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Musical Intelligence

[Music is] the corporealization of the intelligence that is in sound.

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OF ALL the gifts with which individuals may be endowed, none emerges earlier than musical talent. Though speculation on this matter has been rife, it remains uncertain just why musical talent emerges so early, and what the nature of this gift might be. A study of musical intelligence may help us understand the special flavor of music and at the same time illuminate its relation to other forms of human intellect.

Some feeling for the range and sources of early musical gifts can be gleaned by attending a hypothetical musical audition in which the performers are three preschool children. The first child plays a Bach suite for solo violin with technical accuracy as well as considerable feeling. The second child performs a complete aria from a Mozart opera after hearing it sung but a single time. The third child sits down at the piano and plays a simple minuet which he himself has composed. Three performances by three musical prodigies.

But have they all arrived at these heights of youthful talent by the same routes? Not necessarily. The first child could be a Japanese youngster who has participated since age two in the Suzuki Talent Education program and has, like thousands of her peers, mastered the

essentials of a string instrument by the time she enters school. The second child could be a victim of autism, a youngster who can barely communicate with anyone else and who is severely disturbed in several affective and cognitive spheres; still he exhibits an isolated sparing of musical intelligence, such that he can sing back flawlessly any piece he hears. The third could be a young child raised in a musical family who has begun to pick out tunes on his own—a throwback to the precocious young Mozart, Mendelssohn, or Saint-Saens.

Enough children exemplifying each of these patterns have been observed so that we can say with confidence that these performances are genuine phenomena. One can exhibit musical precocity as a result of involvement in a superbly designed instructional regime, by virtue of life in a household filled with music, or despite (or as part of) a crippling malady. Underlying each of these performances, there may well be a core talent, one that has been inherited; but, clearly, other factors are also at work. At the very least, the extent to which the talent is expressed publicly will depend upon the milieu in which one lives.

But these early performances, however charming, mark the barest beginning. Each of these children may go on to achieve a high degree of musical competence, but it is equally possible that one or another will not realize such heights. Accordingly, just as I first introduced linguistic intelligence through the perspective of the poet, I will begin by examining instances of unambiguous musical accomplishment in adulthood—those skills most lavishly found among individuals who make their livelihood as composers. Having presented an "end-state" of musical intelligence, I will then describe some of the core abilities that underlie musical competence in ordinary individuals—those abilities of a relatively microscopic sort, as well as those that involve larger passages of music. In an effort to gain further purchase on the kinds of talent exhibited by our opening trio of children, I will consider aspects of normal development as well as the training of musical skills. As a complement, I will also investigate musical breakdown and, in the course of this discussion, touch upon the brain organization that makes possible musical achievement. Finally, having surveyed the evidence for an autonomous musical intelligence, in our own and other cultures, I shall in conclusion consider some of the ways in which musical intelligence has—and can—interact with other human intellectual competences.

Composing

The twentieth-century American composer Roger Sessions has provided a revealing account of what it is like to compose a piece of music. As he explains it, a composer can be readily identified by the fact that he constantly has "tones in his head"—that is, he is always, somewhere near the surface of his consciousness, hearing tones, rhythms, and larger musical patterns. While many of these patterns are worth little musically and may, in fact, be wholly derivative, it is the composer's lot constantly to be monitoring and reworking these patterns.

Composing begins at the moment when these ideas begin to crystallize and to assume a significant shape. The pregnant musical image can be anything from the simplest melodic, rhythmic, or harmonic fragment to something considerably more elaborate; but in any event, the idea seizes the composer's attention, and his musical imagination begins to work upon it.

In what direction will the idea be taken? As Sessions describes it, the initial idea harbors many implications. Often it stimulates something contrasting or complementary, though the two motifs will remain part of the same overall design. All the ideas that succeed the initial one will bear some relationship to it, at least until that idea has either been completed or abandoned. At the same time, the composer is nearly always certain which elements belong to an elaboration of the original idea and which do not:

> Assuming, as I am doing, that the conception is adequately strong and firmly established, it will govern every move that the composer makes from this point on. . . . Choices are made within a specific framework which, as it grows, exerts an ever greater influence on what is to come.

For the outside world this process may seem mysterious, but for the composer it has a compelling logic of its own:

> What I have called logical musical thinking is the consequential working out of a sustained musical impulse, pursuing a result constantly implicit in it. It is not in any sense a shrewd calculation of what should . . . happen next. The aural imagination is simply the working of the composer's ear, fully reliable and sure of its direction as it must be, in the service of a clearly envisaged conception.

In these efforts, the composer relies on the aforementioned technique of contrast, but also on other dictates of his ear—passages associated with the original idea, passages that articulate or place into proper

proportion the elements of the initial idea. Working with tones, rhythms, and, above all, an overall sense of form and movement, the composer must decide how much sheer repetition, and which harmonic, melodic, rhythmic, or contrapuntal variations, are necessary to realize his conception.

Other composers echo this description of the processes in which they are engaged. In his account, Aaron Copland indicates that composing is as natural as eating or sleeping: "It is something that the composer happens to have been born to do; and because of that it loses the character of a special virtue in the composer's eyes." Wagner said he composed like a cow producing milk, whereas Saint-Saens likened the process to an apple tree producing apples. The sole element of mystery, in Copland's view, is the source of an initial musical idea: as he sees it, themes initially come to the composer as a gift from heaven, much like automatic writing. And that is the reason many composers keep a notebook around. Once the idea has come, the process of development and elaboration follows with surprising naturalness, eventually with inevitability, thanks in part to the many techniques available as well as to the accessibility of structural forms or "schemes" that have evolved over the years. As Arnold Schoenberg puts it, "Whatever happens in a piece of music is nothing but the endless reshaping of a basic shape. Or, in other words, there is nothing in a piece of music but what comes from the theme, springs from it, and can be traced back to it."

What is the source of that musical repository from which the musical ideas come? Another twentieth-century American composer, Harold Shapero, helps us to understand the musical lexicon:

> The musical mind is concerned predominantly with the mechanisms of tonal memory. Before it has absorbed a considerable variety of tonal experiences, it cannot begin to function in a creative way. . . . The musical memory, where its physiological functions are intact, functions indiscriminately; a great percentage of what is heard becomes submerged in the unconscious and is subject to literal recall.

But the materials exploited by the composer are treated differently:

> The creative portion of the musical mind . . . operates selectively, and the tonal material which it offers up has been metamorphized and has become identifiable from the material which was originally absorbed. In the metamorphosis . . . the original tonal memory has been compounded with remembered emotional experiences and it is this act of the creative unconscious which renders more than an acoustical series of tones.

Even as we find consensus among articulate composers about the

naturalness of the act of composition, (if not about the source of the germinal idea), there is considerable agreement about what music is not. Sessions goes to great pains to indicate that language plays no role in the act of composition. Once when stuck in the middle of composition, he was able to describe the source of his difficulty to a young friend. But this was a wholly different medium from the one in which the composer must work:

> I would like to point out that at no time in the course of the actual process of composition were words involved. . . . In no way, however, did these words [told to the friend] help me—nor could they have helped me—to find the precise pattern that I was seeking. . . . I was trying hard to find the proper words with which to describe a sequence of thought that was carried on in the musical medium itself—by which I mean sounds and rhythms, heard to be sure in imagination, but nevertheless heard accurately and vividly.

Igor Stravinsky goes a step further: as he indicated in conversations with Robert Craft, composing is doing, not thinking. It occurs not by acts of thought or will: it is accomplished naturally. And Arnold Schoenberg quotes with approval Schopenhauer's view, "The composer reveals the inmost essence of the world and utters the most profound vision in a language which his reason does not understand, just as a magnetic somnambulist gives disclosures about things which she has no idea of when awake," even as he castigates that philosopher of music, "when he tries to translate details of this language which *the reason does not understand* into our terms" (italics in original). In Schoenberg's view, it is the musical material that must be dealt with: "I don't believe a composer can compose if you give him numbers instead of tones"—this from the individual who has been accused of expelling melody and converting all music to a numerical manipulation system.

For those of us who do not readily compose music—who are excluded from that small minority of mankind "whose minds secrete music"—these processes necessarily have a remote air. We can perhaps identify somewhat more easily with one who performs works written by other individuals—such as an instrumentalist or a singer—or with one charged with interpretation, like a conductor. Yet, in Aaron Copland's view, the skills involved in listening to music have a clear link to those involved in musical creation. As Copland puts it, "The intelligent listener must be prepared to increase his awareness of the musical material and what happens to it. He must hear the melodies, the rhythms, the harmonies, and the tone colors in a more conscious fashion. But above all he must, in order to follow the line of the composer's thought, know something of the principles of musical form." The mu-

sicologist Edward T. Cone suggests, "active listening is, after all a kind of vicarious performance, effected, as Sessions puts it, by 'inwardly reproducing the music.'" In Cone's view, the performer's assignment follows from this prescription: an adequate performance can be best achieved by discovering and making clear the rhythmic life of a composition. Composer and listener come together in full circle in Stravinsky's remark about his intended audience:

> When I compose something, I cannot conceive that it should fail to be recognized for what it is and understood. I use the language of music and my statement in grammar will be clear to the musician who has followed music up to where my contemporaries and I have brought it.

There are several roles that musically inclined individuals can assume, ranging from the avant-garde composer who attempts to create a new idiom, to the fledgling listener who is trying to make sense of nursery rhymes (or other "primer level" music). There may well be a hierarchy of difficulty involved in various roles, with performing exacting more demands than listening does, and composing making more profound (or at least different) demands than performing. It is also probable that certain kinds of music—such as the classical forms under discussion here—are less accessible than folk or musical forms. Yet, there is also a core set of abilities crucial to all participation in the musical experience of a culture. These core abilities should be found in any normal individual brought into regular contact with any kind of music. To the identification of such core musical abilities, I now turn.

The Components of Musical Intelligence

There is relatively little dispute about the principal constituent elements of music, though experts will differ on the precise definition of each aspect. Most central are *pitch* (or melody) and *rhythm*: sounds emitted at certain auditory frequencies and grouped according to a prescribed system. Pitch is more central in certain cultures—for example, those Oriental societies that make use of tiny quarter-tone intervals; while rhythm is correlatively emphasized in sub-Saharan Africa, where the rhythmic ratios can reach a dizzying metrical complexity. Part of the organization of music is horizontal—the relations among the pitches as they unfold over time; and part is vertical, the effects

produced when two or more sounds are emitted at the same time, giving rise to a harmonic or a dissonant sound. Next in importance only to pitch and rhythm is *timbre*—the characteristic qualities of a tone.

These central elements—these "cores" of music—raise the question of the role of audition in the definition of music. There is no question that the auditory sense is crucial to all musical participation: any argument to the contrary would be fatuous. Yet it is equally clear that at least one central aspect of music—rhythmic organization—can exist apart from any auditory realization. It is, in fact, the rhythmic aspects of music that are cited by deaf individuals as their entry point to musical experiences. Some composers, such as Scriabin, have underscored the importance of this aspect of music, by "translating" their works into rhythmic series of colored forms; and other composers, such as Stravinsky, have stressed the significance of seeing music performed, whether by an orchestra or a dance troupe. Thus, it is probably fair to say that certain aspects of the musical experience are accessible even to those individuals who (for one or another reason) cannot appreciate its auditory aspects.

Many experts have gone on to place the affective aspects of music close to its core. On Roger Sessions's account, "music is controlled movement of sound in time. . . . It is made by humans who want it, enjoy it, and even love it." Arnold Schoenberg, hardly known for his sentimentality, put it this way:

> Music is a succession of tones and tone combinations so organized as to have an agreeable impression on the ear and its impression on the intelligence is comprehensible. . . . These impressions have the power to influence occult parts of our soul and of our sentimental spheres and . . . this influence makes us live in a dreamland of fulfilled desires or in a dreamed hell.

In alluding to affect and pleasure, we encounter what may be the central puzzle surrounding music. From the point of view of "hard" positivistic science, it would seem preferable to describe music purely in terms of objective, physical terms: to stress the pitch and rhythmic aspects of music, perhaps recognizing the timbre and the permissible compositional forms; but taking care to avoid the pathetic fallacy, where explanatory power is granted to an object because of the effects it may induce in someone else. Indeed, attempts over the centuries to associate music with mathematics seem a concerted effort to underscore the rationality (if not to deny the emotional powers) of music. Yet hardly anyone who has been intimately associated with music can forbear to mention its emotional implications: the effects it has upon indi-

viduals; the sometimes deliberate attempts by composers (or performers) to mimic or communicate certain emotions; or, to put it in its most sophisticated terms, the claim that, if music does not in itself convey emotions or affects, it captures the *forms* of these feelings. Testimony can be found wherever one looks. Socrates recognized early the links between specific musical modes and different human character traits, associating the Ionian and Lydian modes with indolence and softness, the Dorian and Phrygian modes with courage and determination. Sessions seems to favor this way of speaking:

> Music cannot express fear, which is certainly an authentic emotion. But its movement, in tones, accents, and rhythmic design, can be restless, sharply agitated, violent, and even suspenseful. . . . It cannot express despair, but it can move slowly, in a prevailingly downward direction; its texture can become heavy and, as we are wont to say, dark—or it can vanish entirely.

And even Stravinsky, who in a famous remark once challenged this way of thinking ("Music is powerless to express anything"), later went on to recant: "Today I would put it the other way around. Music expresses itself. . . . A composer works in the embodiment of his feelings and, of course, it may be considered as expressing or symbolizing them." Turning to the experimental laboratory, the psychologist Paul Vitz has demonstrated in a number of studies that higher tones evoke a more positive affect in listeners. And even "cold-hearted" performers have confirmed this link: it is commonly reported that performers are so deeply affected by a given composition that they request to have it played at their funeral. The virtual unanimity of this testimony suggests that when scientists finally unravel the neurological underpinnings of music—the reasons for its effects, its appeal, its longevity—they will be providing an explanation of how emotional and motivational factors are intertwined with purely perceptual ones.

Bearing these core abilities in mind, psychologists have attempted to examine the mechanism by which musical patterns are perceived. For some time, one could discern two radically different approaches to the psychological investigation of music. The more prevalent school has taken what might be called a "bottom-up" approach, examining the ways in which individuals process the building blocks of music: single tones, elementary rhythmic patterns, and other units that allow ready presentation to experimental subjects and are devoid of the contextual information encountered in performances of works of music. Subjects are asked to indicate which of two tones is higher, whether two rhythmic patterns are the same, whether two tones are played by the same

instrument. The precision with which these studies can be carried out makes them appealing to experimental investigators. Yet musicians have often questioned the relevance of findings obtained with such artificial patterns for the larger musical entities typically encountered by human beings.

This skepticism about the possibility of building up to music from its component parts accounts for the appeal of a "top-down" approach to musical perception, where one presents to subjects musical pieces or, at least, healthy musical segments. In such studies, one typically examines reactions to more global properties of music (does it get faster or slower, louder or softer?) and also to metaphoric characterizations of the music (is it heavy or light, triumphant or tragic, crowded or sparse?). What this approach gains in face validity, it typically sacrifices in terms of experimental control and susceptibility to analysis.

It is perhaps inevitable and, to most minds, entirely desirable that a "middle ground" approach has recently come to the fore. The goal here is to sample musical entities that are large enough to bear a non-superficial resemblance to genuine musical (as opposed to simple acoustic) entities, yet sufficiently susceptible to analysis to permit systematic experimental manipulations. Research in this vein has generally involved the presentation to subjects of short pieces, or incomplete fragments of pieces, that have a clear key or a clear rhythm. Subjects are asked to compare completions with one another, to group together pieces in the same key or rhythm patterns, or to fashion their own completions.

Such research reveals that all but the most naïve (or most disabled) subjects appreciate something of the structure of music. That is, given a piece in a certain key, they can judge which sort of ending is more appropriate, which sort is less appropriate; hearing a piece in a certain rhythm, they can group it together with others of similar rhythm or, again, complete the rhythm appropriately. Individuals with a modest amount of musical training or sensitivity are able to appreciate the relationships that obtain within a key—to know that the dominant or the subdominant enjoy a privileged relationship to the tonic—and which keys are musically close to one another so that a modulation between them is appropriate. Such individuals are also sensitive to the properties of a musical contour, appreciating, for example, when one phrase displays a contour that is the converse of a previous phrase. Scales are recognized as a series of tones with a definite structure, and there are expectations about leading tones, resting tones, cadences, and other fixtures of musical compositions. At the most general level, indi-

viduals appear to have "schemas" or "frames" for hearing music—expectations about what a well-structured phrase or section of a piece should be—as well as at least a nascent ability to complete a segment in a way that makes musical sense.

An analogy to language may not be out of place here. Just as one can tease apart a series of levels of language—from the basic phonological level, through a sensitivity to word order and word meaning, to the ability to appreciate larger entities, like stories—so, too, in the realm of music, it is possible to examine sensitivity to individual tones or phrases, but also to look at how these fit together into larger musical structures which exhibit their own rules of organization. And just as these different levels of analysis can—and should—be brought to bear in apprehending a literary work like a poem or novel, so, too, the apprehension of musical works requires the ability to make the local analysis of the "bottom-up" camp as well as the "top-down" schematizations of the Gestalt school. Increasingly, researchers in music are avoiding the Scylla of total concern with detail and ornamentation, and the Charybdis of attention only to overall form, in favor of analyses that take into account aspects at each of these levels and strive for an integration in the Final Analysis. Perhaps in the future, individuals charged with assessing promise in the musical domain will be able to draw on findings from this eclectic approach to musical competence.

The Development of Musical Competence

In Europe during the early years of the century, there was a fair amount of interest in the development of artistic abilities in children, including the growth of musical competence. My opening vignette would have seemed entirely fitting in Vienna seventy-five years ago. For reasons that one could speculate about, this interest rarely crossed the Atlantic. Therefore, little has been firmly established about the normal development of musical competence in our society or, for that matter, about the development of such competence in any culture.

Nonetheless, at least a rough-and-ready portrait of early musical competence can be proposed. During infancy, normal children sing as well as babble: they can emit individual sounds, produce undulating patterns, and even imitate prosodic patterns and tones sung by others with better than random accuracy. In fact, it has recently been claimed by Mechthild Papoušek and Hanus Papoušek that infants as young as

two months are able to match the pitch, loudness, and melodic contour of their mother's songs, and that infants at four months can match rhythmic structure as well. These authorities claim that infants are especially predisposed to pick up these aspects of music—far more than they are sensitive to the core properties of speech—and that they can also engage in sound play that clearly exhibits creative, or generative, properties.

In the middle of the second year of life, children effect an important transition in their musical lives. For the first time, they begin on their own to emit series of punctate tones that explore various small intervals; seconds, minor thirds, major thirds, and fourths. They invent spontaneous songs that prove difficult to notate; and, before long, they begin to produce small sections ("characteristic bits") of familiar songs heard around them—such as the "EI-EI-O" from "Old MacDonald" or "All fall down" from "Ring around the Rosie." For a year or so, there exists a tension between the spontaneous songs and the production of "characteristic bits" from familiar tunes; but, by the age of three or four, the melodies of the dominant culture have won out, and the production of spontaneous songs and of exploratory sound play generally wanes.

Much more so than in language, one encounters striking individual differences in young children as they learn to sing. Some can match large segments of a song by the age of two or three (in this they are reminiscent of our autistic child); many others can emit only the grossest approximations of pitch at this time (rhythm and words generally pose less of a challenge) and may still have difficulty in producing accurate melodic contours at the age of five or six. Still, it seems fair to say that by school age, most children in our culture have a schema of what a song should be like and can produce a reasonably accurate facsimile of the tunes commonly heard around them.

Except among children with unusual musical talent or exceptional opportunities, there is little further musical development after the school years begin. To be sure, the musical repertoire expands, and individuals can sing songs with greater accuracy and expressivity. There is also some increase in knowledge about music, as many individuals become able to read music, to comment critically upon performances, and to employ musical-critical categories, such as "sonata form" or "duple meter." But whereas, in the case of language, there is considerable emphasis in the school on further linguistic attainments, music occupies a relatively low niche in our culture, and so musical illiteracy is acceptable.

Once one casts a comparative glance around the globe, a far wider

variety of musical trajectories becomes manifest. At one extreme are the Anang of Nigeria. Infants scarcely a week old are introduced to music and dancing by their mothers. Fathers fashion small drums for their children. When they reach the age of two, children join groups where they learn many basic cultural skills, including singing, dancing, and playing of instruments. By the age of five, the young Anang can sing hundreds of songs, play several percussion instruments, and perform dozens of intricate dance movements. Among the Venda of Northern Transvaal, young children start with motor response to music and don't even try to sing. The Griots, traditional musicians of Senegambia, require an apprenticeship of several years. In some cultures, wide individual differences are recognized: for example, among the Ewe of Ghana, less talented persons are made to lie on the ground, while a musical master sits astride them and beats rhythms into their body and their soul. In contrast, the aforementioned Anang claim that all individuals are musically proficient; and the anthropologists who studied this group claim never to have encountered in it a "non-musical" member. In some contemporary cultures, musical competence is highly prized: in China, Japan, and Hungary, for example, children are expected to gain proficiency in singing and, if possible, in instrumental performance as well.

Our understanding of levels of musical competence has been significantly enhanced by Jeanne Bamberger, a musician and developmental psychologist at the Massachusetts Institute of Technology. Bamberger has sought to analyze musical development along the lines of Piaget's studies of logical thought, but has insisted that musical thinking involves its own rules and constraints and cannot simply be assimilated to linguistic or logical-mathematical thinking. Pursuing one line of study, she has demonstrated forms of conservation that exist in the realm of music but are not interchangeable with the classical forms of physical conservation: For example, a young child will confuse a tone with the particular bell from which it is made, and will not appreciate that many bells can produce the same tone or that a bell that is moved will retain its sound. On the other hand, the young child may also recognize that no two performances of a song are exactly identical. Such demonstrations underscore the fact that the concept "same" bears a different meaning in music than it does in the mathematical sphere.

Bamberger has called attention to two contrasting ways of processing music, which correspond roughly to "know-how" versus "know-that." In a *figural* approach, the child attends chiefly to the global features of a melodic fragment—whether it gets louder or softer, faster or

slower—and to the "felt" features of groupings—whether a set of tones appears to belong together and to be separated in time from its neighbors. The approach is intuitive, based solely on what is heard irrespective of any theoretical knowledge about music. In contrast, the individual with a *formal mode* of thought can conceptualize his musical experience in a principled manner. Equipped with propositional knowledge about music as a system, he understands what occurs on a measure-by-measure basis and can analyze passages in terms of their time signature. Thus, he can appreciate (and notate) a passage in terms of the number of beats per measure and the occurrence of particular rhythmic patterns against this metrical background.

Ultimately, any individual in our culture who would wish to gain musical competence should master formal musical analysis and representation; but at least initially, this move to the level of "knowledge about music" may involve a cost. Certain important aspects of music that are "naturally" perceived according to the initial "figural" mode of processing may be at least temporarily obscured ("wiped out") as an individual attempts to assess and classify everything according to a formal mode of analysis—to superimpose propositional knowledge upon figural intuitions.

Indeed, the clash between figural and formal modes of processing may even occasion a crisis in the lives of young musicians. According to Bamberger, children treated by their communities as prodigies often advance quite far on the basis of figural apprehension of music. At a certain point, however, it becomes important for them to supplement their intuitive understanding with a more systematic knowledge of music lore and law. This bringing-to-consciousness of what was previously assumed (or ignored) can be unsettling for youngsters, particularly for ones who have depended simply upon their intuition, and who may have a resistance to propositional (linguistic or mathematical) characterizations of musical events. The so-called midlife crisis occurs in the lives of prodigies in adolescence, somewhere between the ages of fourteen and eighteen. If this crisis is not successfully negotiated, it may ultimately prompt the child to cease altogether participating in musical life.

One can posit a pattern of growth for the young musical performer. Up till the age of eight or nine, in a manner reminiscent of the young literary Sartre, the child proceeds on the basis of sheer talent and energy: he learns pieces readily because of his sensitive musical ear and memory, gains applause for his technical skill, but essentially does not expend undue effort. A period of more sustained skill build-

ing commences around the age of nine or so, when the child must begin to practice seriously, even to the extent that it may interfere with his school and his friendships. This may, in fact, occasion an initial "crisis" as the child starts to realize that other values may have to be suspended if his musical career is to be pursued. The second and more pivotal crisis occurs in early adolescence. In addition to confronting the clash between figural and formal ways of knowing, the youth must ask whether he actually wishes to devote his life to music. Earlier, he has been an (often willing) vessel in the grasp of ambitious parents and teachers; now he must ponder whether he himself wants to pursue this calling, whether he wants to use music to express to others what is most important in his own existence, whether he is willing to sacrifice his other pleasures and possibilities for an uncertain future where luck and extra-musical factors (like interpersonal skills) may well prove decisive.

In speaking of musically talented children, I am concerned with a tiny group of children who have been singled out by their families and their communities. It is not known to what extent this number could be significantly increased were values and training methods to change. Still, my opening vignettes offer suggestive clues.

In Japan, the great master Suzuki has shown that large numbers of individuals can learn to play musical instruments extremely well (according to Western standards) even at an early age. To be sure, most of these individuals do not go on to become concert musicians—a result that does not disturb Suzuki, who sees his goal as the training of character, not of virtuoso performance. Suzuki's population may be, to some extent, self-selected. Still, the astonishing performances by large numbers of Japanese children—and by "Suzuki-style youngsters" in other cultural settings as well—indicates that such fluency is a reasonable target for a much larger proportion of the population than is currently the case in the United States. The existence of accomplished singing skill in certain cultural groups (Hungarians influenced by the Kodaly method, or members of the Anang tribe in Nigeria) and of comparably high-quality instrumental performances among Russian Jewish violinists or Balinese gamelon players suggests that musical achievement is not strictly a reflection of inborn ability but is susceptible to cultural stimulation and training.

On the other hand, if there is any area of human achievement in which it pays to have adequate or lavish genetic background, music would be a formidable contender. The extent to which music runs in families—like the Bach, Mozart, or Haydn households—is one possible line of evidence; but nongenetic factors (such as value systems or train-

ing procedures) might be equally responsible in such cases. Probably a more persuasive line of evidence comes from those children who, in the absence of a hospitable family environment, present themselves initially as able to sing very well, to recognize and recall numerous tunes, to pick out melodies on a piano or other instrument. Even the slightest musical stimulation becomes a crystallizing experience. Moreover, once exposed to formal training, these same children appear to pick up requisite skills with great rapidity—as Vygotsky would put it, they exhibit a large zone of potential (or proximal) development. It seems reasonable to regard this ability as the manifestation of a considerable genetic proclivity to hear accurately, to remember, master (and, eventually, produce) musical sequences. And it would seem that both our autistic child and our young composer display considerable genetic potential in the area of music.

A particularly dramatic instance of a talent that announced itself to the world can be found in the saga of the renowned twentieth-century pianist Arthur Rubinstein. Rubinstein came from a family none of whom, in his own words "had the slightest musical gift." As a toddler in Poland, he loved all manner of sounds, including factory sirens, the singing of old Jewish peddlers, and the chants of ice cream sellers. While he refused to speak, he was always willing to sing and thereby created quite a sensation at home. In fact, his abilities soon degenerated into a sport, where everyone tried to reach him by songs, and he himself came to recognize people by their tunes.

Then, when he had attained the advanced age of three, his parents bought a piano so that the older children in the family could have lessons. Though not studying piano himself, Rubinstein reports:

> The drawing room became my paradise. . . . Half in fun, half in earnest, I learned to know the keys by their names and with my back to the piano I would call the notes of any chord, even the most dissonant one. From then on it became mere "child's play" to master the intricacies of the keyboard, and I was soon able to play first with one hand, later with both, any tune that caught my ear . . . All this, of course, could not fail to impress my family—none of whom, I must now admit, including grandparents, uncles, aunts, had the slightest musical gift. . . . By the time I was three and a half years old my fixation was so obvious that my family decided to do something about this talent of mine.

The Rubinsteins in fact took their young prodigy to meet Joseph Joachim, the most celebrated violinist of the nineteenth century, who proclaimed that young Arthur might one day become a great musician, because his talent was extraordinary.

Even given generous dollops of talent, musical achievement need

not follow. For every ten musical prodigies (with the presumptive inborn talent), there are several failed prodigies, some of whom ceased music altogether, others of whom tried but failed to reach the heights of musical achievement. (Even Rubinstein had to confront several crises regarding his own talent and will to make music.) Issues of motivation, personality, and character are generally singled out as decisive here—though luck certainly contributes as well. A musician in our culture must be more than simply technically proficient. One must be able to interpret music, to glean the composer's intentions, to realize and project one's own interpretations, to be a convincing performer. As Rudolf Serkin, one of the leading pianists of our day, has put it:

> Ivan Galamian [the leading violin teacher of the middle twentieth century] believes in taking them young, at 10 or 12. So do I. At that age you can already tell the talent, but not . . . character or personality. If they have personality they will develop into quite something. If not, at least they will play well.

Nearly all composers begin as performers, though some performers begin to compose during the first decade of their lives. (Composing at the level of a world-class artist seems to require at least ten years to flower—no matter how gifted one is.) Why a small percentage of performers become composers has not been much studied, though there are presumably positive (proclivity and skill) as well as negative (shyness, awkwardness) factors that prompt one decision rather than the other. In my own cursory study of this question, I uncovered one common theme. Individuals who later became composers (rather than, or in addition to, performers) found themselves by the age of ten or eleven, experimenting with pieces that they were performing, rewriting them, changing them, turning them into something other than they were—in a word, *de*composing them. Indeed, sometimes this discovery occurs even earlier. Igor Stravinsky recalls trying to pick out at the piano the intervals he had heard "as soon as I could reach the piano—but found other intervals in the process that I liked better, which already made me a composer." For the future composers, like Stravinsky, pleasure came increasingly from what changes they could effect rather than simply from performing the piece literally as well as it could be performed.

In all probability, issues of personality figure crucially here. The sources of pleasure for composition are different from those surrounding performance—the need to create and dissect, to compose and decompose arises from different motivations than the desire to perform or simply to interpret. Composers may resemble poets in the sudden

apprehension of the initial germinal ideas, the need to explore and realize them and the intertwining of emotional and conceptual aspects.

My discussion has been partial to Western civilization in the period following the Renaissance. Cults of performer and composer were far less prevalent in the medieval era; and, indeed, the line between composing and performing does not exist in many cultures. Performers *are* the interpreters and composers; they constantly make small changes in the works that they perform, so that they ultimately build up an *oeuvre;* but they do not self-consciously set themselves off from others as "composers." Indeed, cross-cultural studies suggest a stunning range of attitudes toward the creation of music, with the Congo Basongye feeling uncomfortable with any personal role in the creation of new music; the Plains Indians willing to claim credit for a composition, so long as it was conceived during a vision quest; and the Greenland Eskimos actually judging the results of a fight among men in terms of which antagonist can compose the songs that best convey his side in a dispute. We simply do not know whether individuals in other cultures feel as Beatle John Lennon did during early childhood:

> People like me are aware of their so-called genius at ten, eight, nine . . . I always wondered, "Why has nobody discovered me? In school, didn't they see that I'm more clever than anybody in this school? That the teachers are stupid, too? That all they had was information that I didn't need." It was obvious to me. Why didn't they put me in art school? Why didn't they train me? I was different, I was always different, Why didn't anybody notice me?

Evolutionary and Neurological Facets of Music

The evolutionary origins of music are wrapped in mystery. Many scholars suspect that linguistic and musical expression and communication had common origins and, in fact, split off from one another several hundred thousand, or perhaps even a million, years ago. There is evidence of musical instruments dating back to the Stone Age and much presumptive evidence about the role of music in organizing work groups, hunting parties, and religious rites; but, in this area, theories are all too easy to fabricate and too difficult to discredit.

Still, in studying the ontogenesis of music, we possess at least one advantage not available in questions concerning language. While ties

between human language and other forms of animal communication seem to be limited and controversial, there is at least one instance in the animal kingdom whose parallels to human music are difficult to ignore. That is bird song.

As I noted in discussions of the biological underpinnings of intelligence, much has recently been discovered about the development of song in birds. For present purposes, I wish to stress the following aspects. First of all, one observes a wide range of developmental patterns of bird song, with some species being restricted to a single song learned by all birds, even those that are deaf; other species feature a range of songs and dialects, depending clearly on environmental stimulation of specifiable sorts. We find among birds a remarkable mix of innate and environmental factors. And these can be subjected to that systematic experimentation that is impermissible in the case of human capacities.

Within these different trajectories, there is a prescribed path to development of the final song, beginning with *subsong*, passing through *plastic song*, until the species song or songs are finally achieved. This process bears nontrivial and perhaps striking parallels to the steps through which young children pass as they first babble and then explore fragments from the songs of their environments. To be sure, the ultimate output of human singers is much vaster and more varied than even the most impressive bird repertoire; and this discontinuity between the two vocalizing species needs to be kept in mind. All the same, suggestive analogies in the development of singing should stimulate experimentation that may illuminate more general aspects of musical perception and performance.

But without question, the most intriguing aspect of bird song from the point of view of a study of human intelligence is its representation in the nervous system. Bird song turns out to be one of the few instances of a skill that is regularly lateralized in the animal kingdom—in this case, in the left part of the avian nervous system. A lesion there will destroy bird song, whereas comparable lesions in the right half of the brain exert much less debilitating effects. Moreover, it is possible to examine the bird's brain and to find clear indices to the nature and the richness of songs. Even within a species, birds differ in whether they have a well or a sparsely stacked "library of songs," and this information is "legible" in the avian brain. The stock of song changes across seasons, and this alteration can actually be observed by inspecting the expansion or the shrinkage of the relevant nuclei during different seasons. Thus, while the purposes of bird song are very different from

those of human song ("bird songs are promise of music, but it takes a human being to keep them"), the mechanism by which certain core musical components are organized may well prove analogous to those exhibited by human beings.

Whether there is, in fact, some direct phylogenetic link between human and bird music proves difficult to determine. Birds are sufficiently remote from human beings to make the wholly separate invention of avian and human auditory-oral activity more than just an idle possibility. Perhaps surprisingly, primates exhibit nothing similar to bird song; but individuals in many species do issue sounds that are expressive and can be understood by conspecifics. It seems more likely that in human song we witness the bringing together of a number of abilities—some of which (for example, imitation of vocalic targets) may exist in other forms in other species; others of which (for example, sensitivity to relative as well as absolute pitch, or the ability to appreciate various kinds of musical transformation) are unique to our own.

The temptations are considerable to draw analogies between human music and language. Even in a work devoted to establishing the autonomy of these realms, I have not refrained from drawing such parallels in order to convey a point. It is therefore important to stress the experimental support for this proposed separation. Investigators working with both normal and brain-damaged humans have demonstrated beyond a reasonable doubt that the processes and mechanisms subserving human music and language are distinctive from one another.

One line of evidence in favor of this dissociation has been summarized by Diana Deutsch, a student of the perception of music whose work falls largely in the "bottom-up" tradition. Deutsch has shown that, counter to what had been believed by many psychologists of perception, the mechanisms by which pitch is apprehended and stored are different from the mechanisms that process other sounds, particularly those of language. Convincing documentation comes from studies in which individuals are given a set of tones to remember and then presented with various interfering material. If the interfering material is other tones, recall for the initial set is drastically interfered with (40 percent error in one study). If, however, the interposed material is verbal—lists of numbers, for example—individuals can handle even large amounts of interference without material effect on the memory for pitch (2 percent error in the same study). What makes this finding particularly compelling is that it surprised the subjects themselves. Apparently, individuals expect that the verbal material will interfere with

the melodic material and are frankly incredulous when they are so little affected.

This specialness of musical perception is confirmed dramatically by studies of individuals whose brains have been damaged as a result of stroke or other kinds of trauma. To be sure, there are cases in which individuals who have become aphasic have also exhibited diminished musical ability; but the key finding of this research is that one can suffer significant aphasia without any discernible musical impairment, even as one can become disabled musically while still retaining one's fundamental linguistic competences.

The facts are as follows: Whereas linguistic abilities are lateralized almost exclusively to the left hemisphere in normal right-handed individuals, the majority of musical capacities, including the central capacity of sensitivity to pitch, are localized in most normal individuals in the right hemisphere. Thus, injury to the right frontal and temporal lobes causes pronounced difficulties in discriminating tones and in reproducing them correctly, even as injuries in the homologous areas in the left hemisphere (which cause devastating difficulties in natural language) generally leave musical abilities relatively unimpaired. Appreciation of music also seems to be compromised by right hemisphere disease. (As the names promise, amusia is a disorder distinct from aphasia.)

Once one dons a fine lens, a far more complicated picture emerges, one interestingly more diverse than that found in the case of language. While the syndromes of language seem to be uniform, even across cultures, a great variety of musical syndromes can be found even within the same population. Accordingly, while some composers (like Maurice Ravel) have become amusic following the onset of aphasia, other composers have succeeded in continuing to compose despite a significant aphasia. The Russian composer, Shebalin, proved able to compose very competently despite a severe Wernicke's aphasia; and several other composers, including one whom I studied with my colleagues, retained their composing prowess. Similarly, while the ability to perceive and criticize musical performances seems to rely on right hemisphere structures, certain musicians have exhibited difficulties following injury to the left temporal lobe.

Yet another fascinating wrinkle has been recently uncovered. In most tests with normal individuals, musical abilities turn out to be lateralized to the right hemisphere. For example, in tests of dichotic listening, individuals prove better able to process words and consonants presented to the right ear (left hemisphere), while more success-

ful at processing musical tones (and often other environmental noises as well) when these have been presented to the right hemisphere. But there is a complicating factor. When these, or more challenging tasks, are posed to individuals with musical training, there are increasing left hemisphere, and decreasing right hemisphere, effects. Specifically, the more musical training the individual has, the more likely he will draw at least partially upon the left hemisphere mechanisms in solving a task that the novice tackles primarily through the use of right hemisphere mechanisms.

An image of musical competence crossing the corpus callosum as training accrues must not be taken too far. For one thing, it is not found with every musical skill: for instance, Harold Gordon found that even musicians performed chord analysis with the right, rather than with the left, hemisphere. For another, it is not exactly clear *why* increasing left hemisphere effects are found with training. While the actual processing of music may change loci, it is also possible that the mere affixing of verbal labels to musical fragments brings about *apparent* left hemisphere dominance for musical analysis. Trained musicians may be able to use "formal" linguistic classifications as aids where untrained subjects must fall back on purely figural processing capacities.

What must be stressed in this review, however, is the surprising variety of neural representations of musical ability found in human beings. In my own view, this range rests on at least two factors. First of all, there is the tremendous range of types and degrees of musical skill found in the human population; since individuals differ so much in what they can do, it is conceivable that the nervous system can offer a plurality of mechanisms for carrying out these performances. Second, and relatedly, individuals may make their initial encounter with music through different media and modalities and, even more so, continue to encounter music in idiosyncratic fashion. Thus, while every normal individual is exposed to natural language primarily through listening to others speak, humans can encounter music through many channels: singing, playing instruments by hand, inserting instruments into the mouth, reading of musical notation, listening to records, watching dances, or the like. Even as the way in which written language is represented neurally reflects the kind of script used in one's culture, the various ways in which music can be processed cortically probably reflect the wealth of ways in which humans have found to make and absorb music.

Given the apparently greater variability in brain representation,

how does this affect my claim that music qualifies as an autonomous intellectual competence? To my mind, the variation in representation does not compromise my argument. So long as music is represented *with some localization* in an individual, it is not relevant that one individual's localization is not identical to another's (after all, if one includes left-handers, the variety of linguistic localization proves much greater than if one ignores them). Second, what is really crucial is whether other abilities predictably occur together with music, such that when musical ability is destroyed, so are the others. So far as I am aware, none of the claims with respect to musical breakdown suggest any systematic connection with other faculties (such as linguistic, numerical, or spatial processing): music seems, in this regard, *sui generis*, just like natural language.

Finally, I believe that, in the last analysis, there may be considerable underlying regularity in musical representation across individuals. The equation for explaining that uniformity may be complicated, having to take into account the means by which music is initially encountered and learned, the degree and type of training an individual has, the kinds of musical tasks that person is called upon to perform. Given this variety , we may need to examine large numbers of individuals before the genuine uniformities become evident. Perhaps once we have refined the proper analytic tools for studying various forms of musical competence, we may find that it is even more lateralized and localized than human language. Indeed, recent studies converge on the right anterior portions of the brain with such predictability as to suggest that this region may assume for music the same centrality as the left temporal lobe occupies in the linguistic sphere.

Unusual Musical Talents

Patterns of unique breakdown of musical ability provide one strong line of evidence for the autonomy of musical intelligence. Its selective preservation or early appearance in otherwise unremarkable individuals is another line. I have already suggested that unusual musical aptitude is a regular concomitant of certain anomalies, such as autism. Indeed, the literature is filled with accounts of astonishing musical and acoustical feats carried out by autistic youngsters. There have also been more than a few *idiots savants* with unusual musical skills. One such

child named Harriet was able to play "Happy Birthday" in the style of various composers, including Mozart, Beethoven, Verdi, and Schubert. That this was not rote familiarity was suggested by the fact that she could recognize a version that her physician had contrived in the style of Haydn. Harriet exerted her musical passions in other ways—for example, knowing the personal history of every member of the Boston Symphony Orchestra. At the age of three, her mother called her by playing incomplete melodies, which the child would then complete with the appropriate tone in the proper octave. Other children described in the literature have been able to remember hundreds of tunes or pick out familiar melodies on a variety of instruments.

While the retarded or autistic child may cling to music because it represents a relative island of preservation in a sea of impairments, there are also more positive signs of isolation, where an otherwise normal child simply displays a precocious ability in the musical sphere. Tales abound about young artists. One composer recalls, "I can never understand how anyone could have difficulty recognizing tones and deciphering musical patterns. It's something I've been doing since the age of three at least." Igor Stravinsky was apparently able to remember the first music that he ever heard:

> A bristling fife-and-drum marine band from the marine barracks near our house. . . . This music, and that of the full band which accompanied the Horse Guards, penetrated my nursery every day, and the sound of it, especially of the tuba and the piccolos and drums, was the pleasure of my childhood. . . . The noises of wheels and horses and the shots and whipcracks of coachmen must have penetrated my earliest dreams: they are, at any rate, my first memory of the street of childhood.

Stravinsky recalls that when he was two, some nearby countrywomen had sung an attractive and restful song on their way home from the fields in the evening. When his parents asked him what he had heard, "I said I had seen the peasants and I had heard them sing, and I sang what they had sung. Everyone was astonished and impressed at this recital and I heard my father remark that I had a wonderful ear." Yet, as we have seen, even the most gifted young child will take about ten years to achieve those levels of performance or composition that we associate with mastery of the musical realm.

A different set of prized musical capacities may be gleaned from scattered studies of musical performance in other cultural settings. In traditional cultures, one generally finds far less of an emphasis on the individual performance or on an innovative departure from cultural

norms, far more of a treasuring of individuals who have mastered the genres of their culture and can elaborate upon them in appealing ways. One finds in pre-literate cultures individuals with prodigious memories for tunes, memories that rival those displayed elsewhere with stories. (Indeed, musical gifts are often equated with memory for lyrics.) Equipped with basic schemas, such individuals have the option of combining portions of chants in countless ways that give pleasure and prove appropriate to the circumstance for which they have been contrived.

The properties valued in diverse cultures will also determine which youngsters are picked out to participate actively in the musical life of the community. Thus, where rhythmic, dance, or group participation in music is at a premium, individuals with gifts in these areas will be especially esteemed. And sometimes factors that we would consider decidedly nonmusical, such as a visually attractive performance, are considered at a premium.

There are also instructive adaptations to limited cultural resources. For example, in *Naven*, Gregory Bateson relates the following anecdote: Two individuals were playing flutes, neither of which had stops. It was not possible to play the whole tune on a single instrument. So the performers contrived to alternate pitches between them, so that all the tones in the tune could be emitted at the proper time.

Relation to Other Intellectual Competences

The various lines of evidence that I have reviewed in this chapter suggest that, like language, music is a separate intellectual competence, one that is also not dependent upon physical objects in the world. As is the case with language, musical facility can be elaborated to a considerable degree simply through exploration and exploitation of the oral-aural channel. In fact, it scarcely seems an accident that the two intellectual competences that, from the earliest period of development, can proceed without relation to physical objects, both rely on the oral-auditory system; though, as it turns out, they do so in neurologically distinct ways.

But, in closing, it is equally important to note important and integral links that obtain between music and other spheres of intellect. Richard Wagner located music centrally in his *Gesamtkunstwerk* ("pan-

artistic work"), and that placement was not altogether an arrogance: in fact, music does relate in a variety of ways to the range of human symbol systems and intellectual competences. Moreover, precisely because it is not used for explicit communication, or for other evident survival purposes, its continuing centrality in human experience constitutes a challenging puzzle. The anthropologist Lévi-Strauss is scarcely alone among scientists in claiming that if we can explain music, we may find the key for all of human thought—or in implying that failure to take music seriously weakens any account of the human condition.

Many composers, Sessions among them, have stressed the close ties that exist between music and bodily or gestural language. On some analyses, music itself is best thought of as an extended gesture—a kind of movement or direction that is carried out, at least implicitly, with the body. Echoing this sentiment, Stravinsky has insisted that music must be *seen* to be properly assimilated: thus, he was partial to the ballet as a mode of performance and always insisted that one observe instrumentalists when they were performing a piece. Young children certainly relate music and body movement naturally, finding it virtually impossible to sing without engaging in some accompanying physical activity; most accounts of the evolution of music tie it closely to primordial dance; many of the most effective methods of teaching music attempt to integrate voice, hand, and body. Indeed, it is probably only in recent times and in Western civilization, that the performance and appreciation of music, quite apart from movement of the body, has become just the pursuit of a tiny "vocal" minority.

Ties between music and spatial intelligence are less immediately evident but, quite possibly, no less genuine. The localization of musical capacities in the right hemisphere has suggested that certain musical abilities may be closely tied to spatial capacities. Indeed, the psychologist Lauren Harris quotes claims to the effect that composers are dependent upon powerful spatial abilities, which are required to posit, appreciate, and revise the complex architectonic of a composition. And he speculates that the dearth of female composers may be due not to any difficulty with musical processing *per se* (witness the relatively large number of female singers and performers) but rather to the relatively poorer performances in spatial tasks exhibited by females.

Recently, an intriguing possible analogue between musical and spatial abilities has come to light. Arthur Lintgen, a physician in Philadelphia, has astonished onlookers by his ability to recognize musical pieces simply by studying the pattern of grooves on a phonograph record. No claims for magic here. According to Lintgen, phonographic

grooves vary in their spacing and contours depending on the dynamics and frequency of the music. For instance, grooves containing soft passages look black or dark gray, while the grooves turn silvery as the music becomes louder or more complicated. Lintgen performs his stunt by correlating vast knowledge of the sound properties of classical music with the distinctive pattern of grooves on records, including ones that he has never seen recorded before. For our purposes, the relevant aspect of Lintgen's demonstration is the implication that music has some analogues in other sensory systems; perhaps, then, a deaf person can come to appreciate at least certain aspects of music by studying these patterns (though presumably not so much as a blind person who is able to "feel" a piece of sculpture). And in cultures where nonauditory aspects of music contribute to its effect, at least these features can be appreciated by those individuals who, for one or another reason, are deaf to tone.

I have already noted the universally acknowledged connection between musical performance and the feeling life of persons; and since feelings occupy a central role in the personal intelligences, some further comments may be in order here. Music can serve as a way of capturing feelings, knowledge about feelings, or knowledge about the forms of feeling, communicating them from the performer or the creator to the attentive listener. The neurology that permits or facilitates this association has by no means been worked out. Still, it is perhaps worth speculating that musical competence depends not upon cortical analytic mechanisms alone, but also upon those subcortical structures deemed central to feeling and to motivation. Individuals with damage to the subcortical areas, or with disconnection between cortical and subcortical areas, are often described as being flat and devoid of affect; and while it has not been commented upon in the neurological literature, it is my observation that such individuals seem rarely to have any interest in or attraction to music. Quite instructively, one individual with extensive right hemisphere damage remained able to teach music and even to write books about it, but lost the ability and the desire to compose. According to his own introspection, he could no longer retain the feeling of the whole piece, nor a sense of what worked and what did not work. Another musician with right hemisphere disease lost all aesthetic feelings associated with his performances. Perhaps these feeling aspects of music prove especially brittle in the instance of damage to the right hemisphere structures, whether they be cortical or subcortical.

Much of the discussion in this chapter has been centered around

an implicit comparison between music and language; and it has been important for my claim of autonomous intellectual competences to show that musical intelligence has its own developmental trajectory as well as its own neurological representation, lest it be swallowed up by the omnivorous jaws of human language. Still, I would be derelict if I did not note the continuing efforts on the part of musicologists, and also of well-informed musicians like Leonard Bernstein, to search for nontrivial parallels between music and language. Recently, these efforts have centered about attempts to apply at least parts of Noam Chomsky's analysis of the generative structure of language to the generative aspects of musical perception and production. These commentators are quick to point out that not all aspects of language are directly analogous to music: for example, the whole semantic aspect of language is radically underdeveloped in music; and the notion of strict rules of "grammaticality" is once again extraneous in music, where violations are often prized. Still, if these caveats are borne in mind, there do seem to be nontrivial parallels in the modes of analysis which seem appropriate for natural language, on the one hand, and for Western classical music (1700–1900), on the other. But whether these parallels occur chiefly (or even solely) at the level of formal analysis, or whether they also obtain with respect to the fundamental modes of information processing featured in these two intellectual spheres, has by no means been resolved.

I have saved until last that area of intellectual competence that, in popular lore, has been most closely tied to music—the mathematical sphere. Dating back to the Classical discoveries of Pythagoras, the links between music and mathematics have attracted the imagination of reflective individuals. In medieval times (and in many non-Western cultures), the careful study of music shared many features with the practice of mathematics, such as an interest in proportions, special ratios, recurring patterns, and other detectable series. Until the time of Palestrina and Lasso, in the sixteenth century, mathematical aspects of music remained central, though there was less overt discussion than before about the numerical or mathematical substrata of music. As harmonic concerns gained in ascendancy, the mathematical aspects of music became less apparent. Once again, however, in the twentieth century—first, in the wake of twelve-tone music, and more recently, because of the widespread use of computers—the relationship between musical and mathematical competences has been widely pondered.

In my own view, there are clearly musical, if not "high math," elements in music: these should not be minimized. In order to appreci-

ate the operation of rhythms in musical work, an individual must have some basic numerical competence. Performances require a sensitivity to regularity and ratios that can sometimes be quite complex. But this remains mathematical thinking only at a relatively basic level.

When it comes to an appreciation of basic musical structures, and of how they can be repeated, transformed, embedded, or otherwise played off one against another, one encounters mathematical thought at a somewhat higher scale. The parallels have impressed at least some musicians. Stravinsky comments:

> [Musical form] is at any rate far closer to mathematics than to literature . . . certainly to something like mathematical thinking and mathematical relationships . . . Musical form is mathematical because it is ideal, and form is always ideal . . . though it may be mathematical, the composer must not seek mathematical formula.
>
> I know . . . that these discoveries are abstract in a similar sense.

A sensitivity to mathematical patterns and regularities has characterized many composers, ranging from Bach to Schumann, who have given vent to this interest, sometimes overtly, sometimes through a kind of playful exploration of possibilities. (Mozart even composed music according to the roll of dice.)

Evidently, there is no problem in finding at least superficial links between aspects of music and properties of other intellectual systems. My own hunch is that such analogies can probably be found between any two intelligences, and that, in fact, one of the great pleasures in any intellectual realm inheres in an exploration of its relationship to other spheres of intelligence. As an aesthetic form, music lends itself especially well to playful exploration with other modes of intelligence and symbolization, particularly in the hands (or ears) of highly creative individuals. Yet, according to my own analysis, the core operations of music do not bear intimate connections to the core operations in other areas; and therefore, music deserves to be considered as an autonomous intellectual realm. In fact, this autonomy should be underscored as we look more closely in the next chapter at those forms of intelligence whose connection to music has most often been alleged—logical and mathematical forms of thought.

In my own view, the task in which musicians are engaged differs fundamentally from that which preoccupies the pure mathematician. The mathematician is interested in forms for their own sake, in their own implications, apart from any realization in a particular medium or from any particular communicative purpose. He may choose to analyze

music and even have gifts for doing so; but from the mathematical point of view, music is just another pattern. For the musician, however, the patterned elements must appear in sounds; and they are finally and firmly put together in certain ways not by virtue of formal consideration, but because they have expressive power and effects. Despite his earlier remarks, Stravinsky contends that "music and mathematics are not alike." The mathematician G. H. Hardy had these differences in mind when he pointed out that it was music which could stimulate emotions, accelerate the pulse, cure the course of asthma, induce epilepsy, or calm an infant. The formal patterns that are a mathematician's *raison d'être* are for musicians a helpful, but not essential ingredient for the expressive purposes to which their own capacities are regularly marshaled.